

# Adaptive Augmenting Control and Launch Vehicle Adaptive Control Flight Experiments (LVAC)

Completed Technology Project (2013 - 2014)



## Project Introduction

Researchers at NASA Armstrong are working to further the development of an adaptive augmenting control algorithm (AAC). The AAC was developed to improve the performance and robustness of NASA's Space Launch System (SLS) during extreme, unanticipated events well outside the rocket's design envelope. The SLS is expected to produce more thrust and deliver more payload to orbit than any other launch vehicle, opening the way to new frontiers of space exploration. The AAC will use sensed data to autonomously adjust to unexpected conditions during flight to ensure that the SLS does not deviate from its trajectory or experience unstable propellant slosh or vehicle flexure.

A series of LVAC flight experiments conducted at Armstrong successfully increased the technology readiness level of an adaptive augmenting control (AAC) algorithm from 5 to 7. To validate the algorithm's effectiveness, researchers installed the prototype AAC flight software into Armstrong's Full-Scale Advanced Systems Testbed (FAST), giving it full authority control over the aircraft's aerodynamic effectors. Armstrong's FAST aircraft then simulated multiple failure scenarios the SLS may experience as it makes its way from the launch pad to booster separation. These tests provided valuable data that both proved the AAC technology and will aid its future development.

**Work to date:** The LVAC experiment included six research flights in late 2013. The FAST aircraft flew trajectories similar to the ones the SLS will follow, and the system was evaluated in a variety of scenarios for up to 70 seconds at a time, matching the SLS dynamics for the majority of its flight from liftoff to solid rocket booster separation. A total of 104 test points were completed, covering 14 simulated failure scenarios and off-nominal events. The controller was evaluated with and without adaptive control for each test case to provide a basis for comparison. In the final flights, two experienced test pilots provided evaluations of interactions between the manual steering mode and the AAC for several of the test cases.

**Looking ahead:** The flight test data are being used to refine the AAC software and plans for future tests. The first flight of the SLS, with the AAC algorithm enabled, is scheduled for 2018.

**NASA Partners:** Marshall Space Flight Center, Engineering and Safety Center, and Space Technology Mission Directorate's Game Changing Development Program

**Benefits:**



NASA's Full-Scale Advanced Systems Testbed (FAST) aircraft during LVAC experiment (#3)

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- **Cost-effective:** Enabled the AAC to be evaluated in-flight without having to be launched into space
- **Systematic:** Allowed multiple, repeated tests with different configurations to compare and isolate characteristics of the design
- **Unique:** Provided full-scale, high-performance piloted testbed with a proven research flight control system, extensive research instrumentation, data downlink for real-time experiment monitoring, and an experienced flight research team
- **Innovative:** FAST test team proposed and supported additional AAC flight test objectives as the project progressed

**Applications:** The AAC algorithm has applications to civilian, fly-by-wire transports, and high-performance military aircraft. The techniques for conducting the LVAC experiment, and the metrics used in evaluating its results, are applicable to flight research into other adaptive control methods and autonomous systems.

## Anticipated Benefits

- **Cost-effective:** Enabled the AAC to be evaluated in-flight without having to be launched into space
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- **Unique:** Provided full-scale, high-performance piloted testbed with a proven research flight control system, extensive research instrumentation, data downlink for real-time experiment monitoring, and an experienced flight research team
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## Organizational Responsibility

### Responsible Mission Directorate:

Space Technology Mission Directorate (STMD)

### Lead Center / Facility:

Armstrong Flight Research Center (AFRC)

### Responsible Program:

Center Innovation Fund: AFRC CIF

## Project Management

### Program Director:

Michael R Lapointe

### Program Manager:

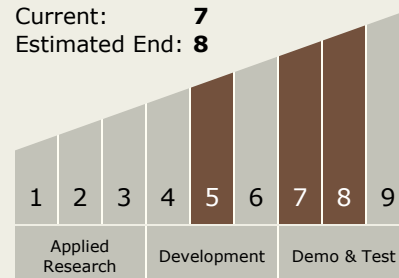
David F Voracek

### Principal Investigator:

Curtis E Hanson

## Technology Maturity (TRL)

Start: 5  
Current: 7  
Estimated End: 8



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## Primary U.S. Work Locations and Key Partners

## Technology Areas

## Primary:

- TX15 Flight Vehicle Systems
  - └ TX15.2 Flight Mechanics
    - └ TX15.2.3 Flight Mechanics Testing and Flight Operations

Organizations Performing Work	Role	Type	Location
★Armstrong Flight Research Center(AFRC)	Lead Organization	NASA Center	Edwards, California
●Marshall Space Flight Center(MSFC)	Supporting Organization	NASA Center	Huntsville, Alabama
●NASA Engineering and Safety Center Program(NESC)	Supporting Organization	NASA Program	
●Space Technology Mission Directorate(STMD)	Supporting Organization	NASA Mission Directorate	

## Primary U.S. Work Locations

Alabama	California
Virginia	

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## Images



### **NASA's Full-Scale Advanced Systems Testbed (FAST) aircraft during LVAC experiment**

NASA's Full-Scale Advanced Systems Testbed (FAST) aircraft during LVAC experiment (#1)  
(<https://techport.nasa.gov/image/16611>)



### **NASA's Full-Scale Advanced Systems Testbed (FAST) aircraft during LVAC experiment**

NASA's Full-Scale Advanced Systems Testbed (FAST) aircraft during LVAC experiment (#3)  
(<https://techport.nasa.gov/image/16613>)



### **NASA's Full-Scale Advanced Systems Testbed (FAST) aircraft during LVAC experiment**

NASA's Full-Scale Advanced Systems Testbed (FAST) aircraft during LVAC experiment (#2)  
(<https://techport.nasa.gov/image/16612>)

## Stories

LVAC Success Story  
(<https://techport.nasa.gov/file/22078>)